

TESTS ON COMBINED STAGED COMBUSTION, SNCR & REBURNING FOR NO_x CONTROL on INDUSTRIAL AND UTILITY BOILERS

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- u **Coal Tech's Approach to Emission Control**
- u **Combustion & Post Combustion NO_x Control Tests in a 20 MMBtu/hr Boiler**
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- u **Conclusions**

Coal Tech's Approach to Emission Control

- u Low capital and process cost are the prerequisites for market acceptance
- u e.g. Cheap “low NO_x burners” versus expensive SCR
- u Low cost through multi-pollutant control processes
- u e.g. Combustion & post-combustion NO_x/SO₂
- u Integrated total emission control
- u NO_x/SO₂/Volatile trace metals/CO₂

Emission Control Implementation

- u Process development in 20 MMBtu/hour commercial scale multi-fuel combustor- boiler
 - Primary focus on low cost in design of tests
 - Isolate pollutant with SO₂/NO_x generator
 - Numerous short duration parametric tests
- u Validate processes in under 100 MW coal fired utility boilers

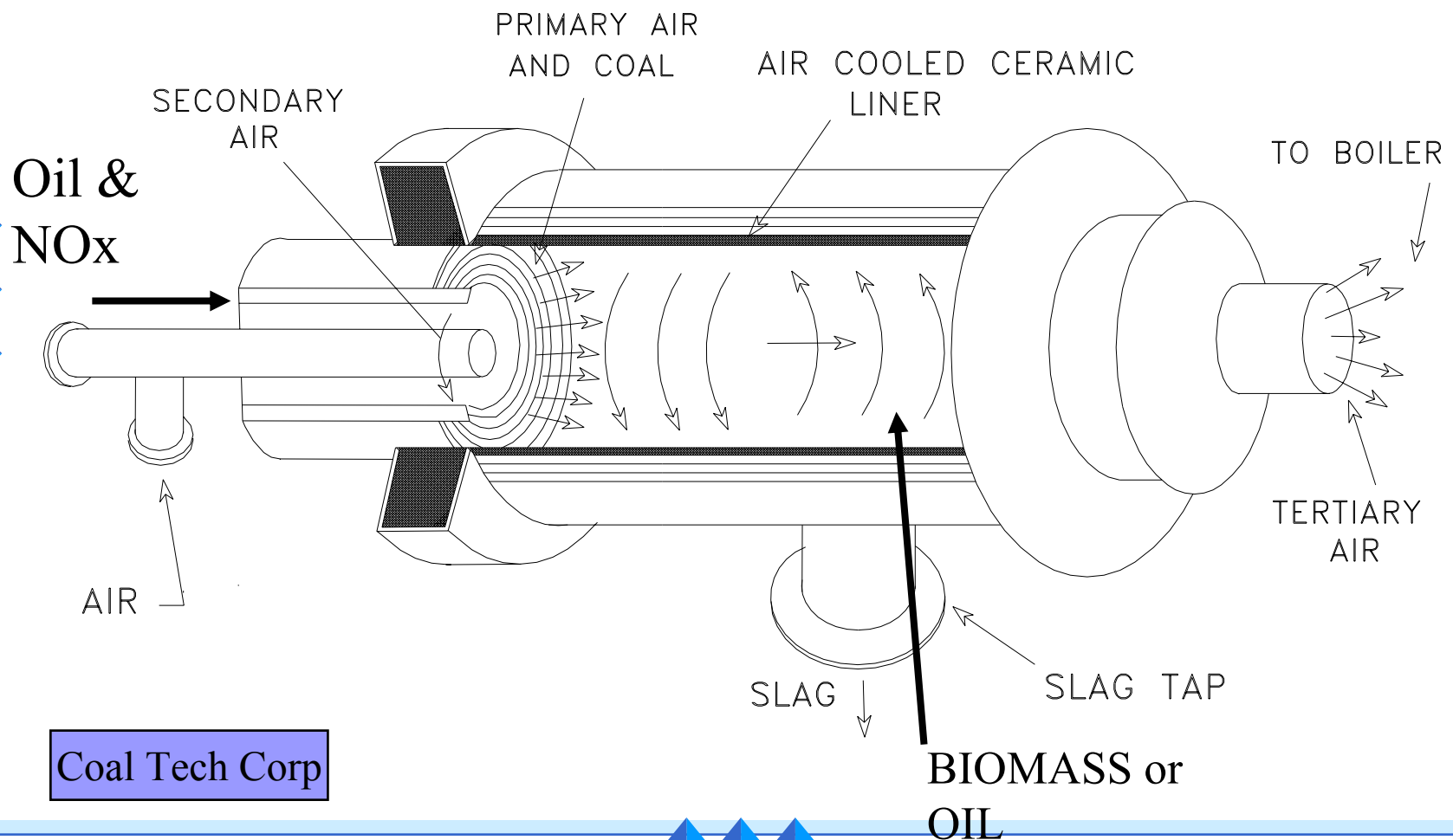
Coal Tech's NO_x Control Technologies

- **Staged, Fuel Rich-Fuel Lean Combustion**
- **Post Combustion SNCR**
- **Post Combustion Reburn with**
 - Liquid fuel and/or
 - Solid fuels, including Biomass
- **Combustion & Post Combustion Combined SO₂/NO_x Control**
 - Lowers process cost
 - Lowers mercury & carbon dioxide control costs

20 MMBtu/hr COMBUSTOR & BOILER

- u (1987-1993)- 1st Generation Combustor-Boiler development- Williamsport, PA**
- u (1994-1997) 2nd Generation Combustor-Boiler development- Philadelphia, Pa**
- u (1997-2004) Emission control development**

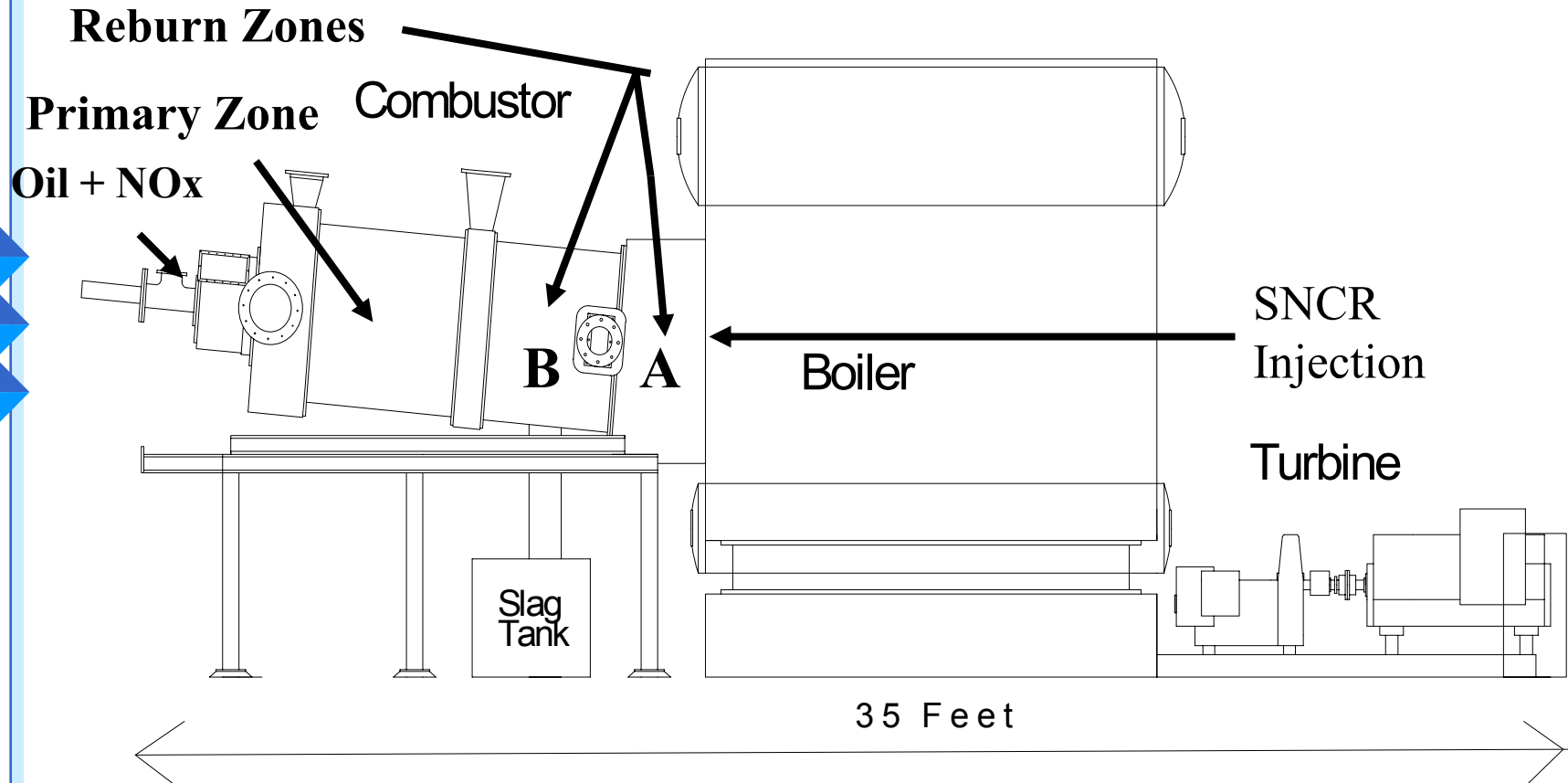
COAL TECH'S AIR COOLED, SLAGGING CYCLONE COAL COMBUSTOR



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20 MMBtu/hr COMBUSTOR-BOILER

Philadelphia, PA

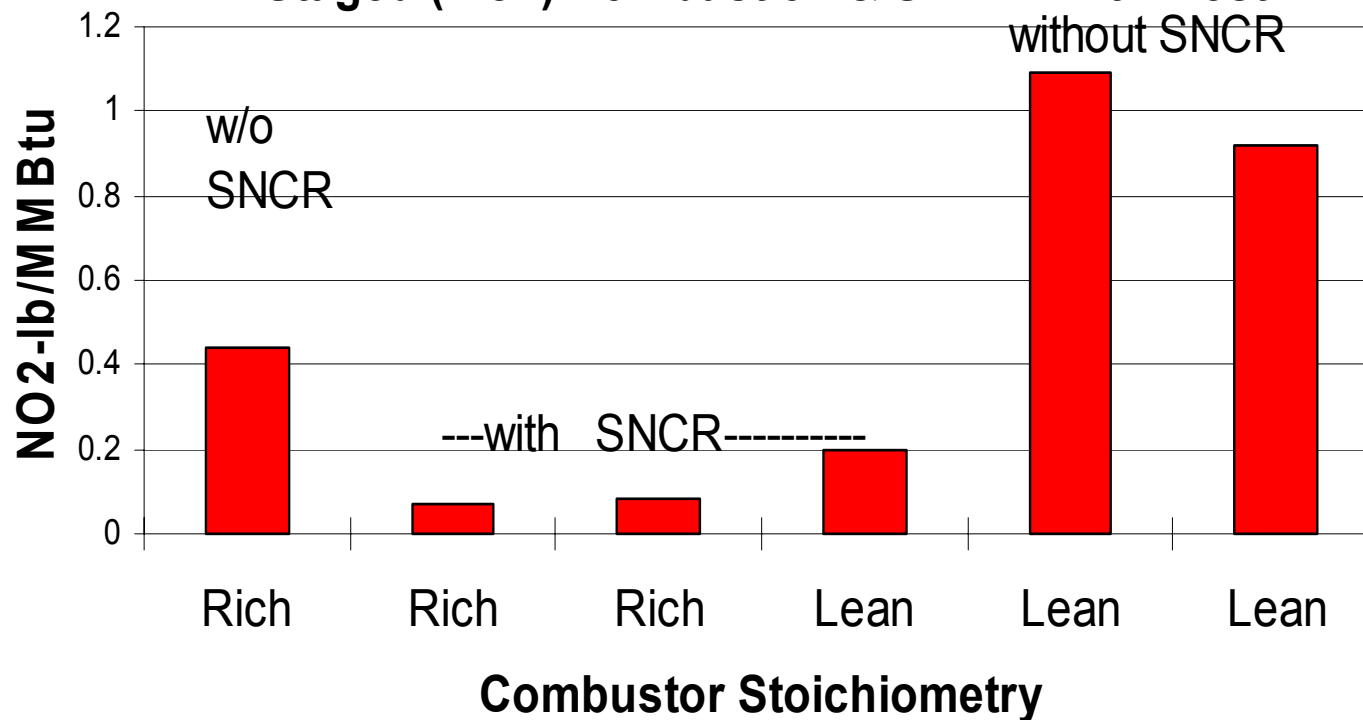


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Best NO_x Results from 20 MMBtu/hr Coal Combustor-Boiler

- u Without NO_x Control: 1.0 lb/MMBtu**
- u Staged Combustion: 0.33 lb/MMBtu, or 67% red.**
- u SNCR: 0.15 lb/MMBtu, or 80% reduction**
- u Staged Comb.+SNCR: 0.07 lb/MMBtu =93% red.**
- u Reburn w. 9% reburn oil+SNCR: 84% reduction**
- u Reburn w. biomass (sawdust)=74%local reduct.**

NO_x Emissions from 20 MMBtu/hr Combustor-Boiler- Staged (Rich) Combustion & SNCR 1/7/97 Test



Ammonia Slip with SNCR in 20 MMBtu/hr Combustor-Boiler

Combustor SR1	NO2 (#/MMBtu)	NH3 Slip (ppm)	%NO_x Reduction
1.31	0.9	0	0
1.31	0.37	5.4	59
1.31	0.54	6.2	40

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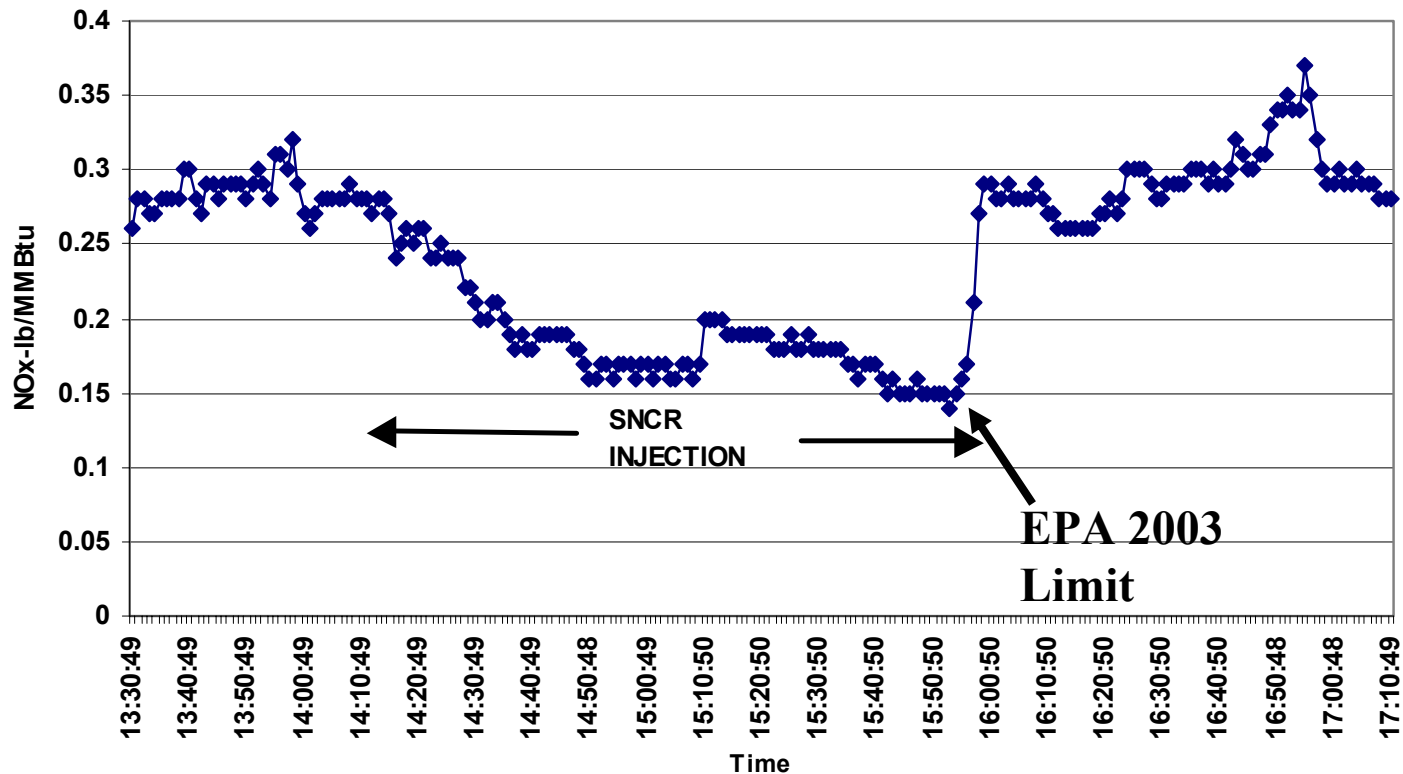
Test Date 2/20/97

Non Catalytic Reduction NO_x Tests in 37 MW Boiler

Test Day	# Injectors	NO _x , lb/MMBtu	%NO _x Reduction	NH ₃ Slip
8/7/97	0	1.07	0	0
8/7/97	1	0.6	40	8.7
8/7/97	1	0.6	40	7.6

Coal Tech's SNCR NO_x Process Test on 50 MW Coal Power Plant-11/11/2003

Est. operating cost=\$400/ton NO_x removed



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Summary of NO_x Reburn Tests in 20 MMBtu/hr Combustor-Boiler with Oil or Biomass

- u High reburn rate due to high excess air in initial primary combustion zone (ie. Stoichiometric Ratio, Sri)

Fuel	SR _i	Q, (% of total Heat In)	NO _x Reduction measured in stack (%)
Oil	>>1	22 to 32	26 to 44
Oil	>1	9	84 (max)
Biomass	>>1	17 to 42	65 (max)

Limited Extent of Reburn in Boiler Zone “A” Lowers NO_x Reduction with Oil & Biomass

% reburn fuel over total fuel	% NO _x reduction in reburn zone	%NO _x reduction at stack
24% Oil reburn	91%	59% (With SNCR) [Comb. gas bypasses reburn zone]
33% Biomass reburn	74%	26% (w/o SNCR) [Unburned biomass blown out of Zone “A”]

Extended Oil Reburn in Combustor Zone “B” Increases NO_x Reduction at Stack

% oil reburn fuel over total fuel	% NO _x reduction at stack
16%	20%
24%	35%
31%	45%
35%	70%

High reburn fuel % due to high excess air in primary combustion zone

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Biomass Reburn in Combustor Zone “B”

% biomass reburn fuel over total fuel	% NO _x reduction in stack
35%	32%
42%	32%
49%	65%

-Solid particle biomass yields less uniform reburn zone flame than oil & much lower NO_x % reduction (almost 1/2 less)

Impact of Reburn Gas Temperature on NO_x Reduction

%Reburn oil of total heat input	Initial gas temperature, oF	Reburn gas temperature, oF	%NO _x reduced @ stack
20	1700	2500	43
27	1800	2850	39
24	1900	3050	35

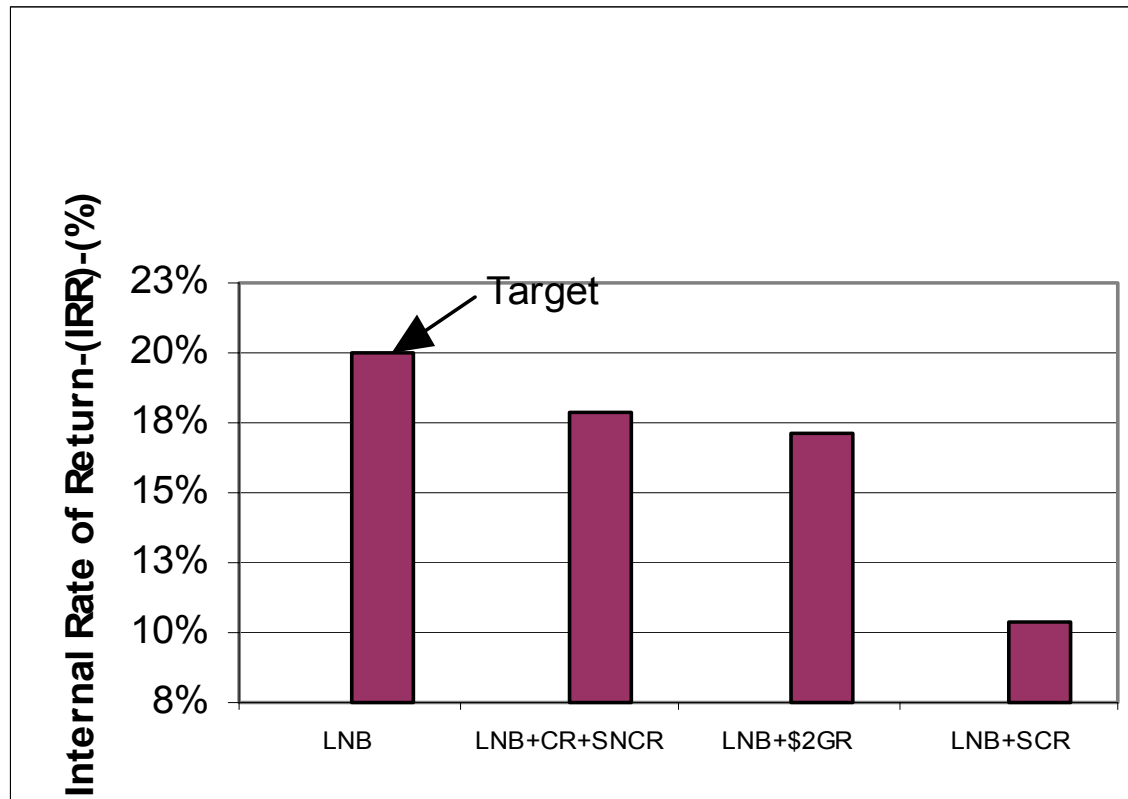
Thermal NO_x reduces reburn effect

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Conclusions from NO_x Reburn Tests

- u To maximize reburn efficiency, excess air in primary combustion zone must be minimized
- u Liquid fuel (oil) is much more efficient than solid particle fuel (biomass) in reducing NO_x due to much greater uniformity of reburn combustion zone
- u Need to limit bypass of untreated combustion gas around reburn zone

Internal Rate of Return for Various NO_x Control Methods



LNB=Low NO_x
Burner

CR=Reburn with
Coal

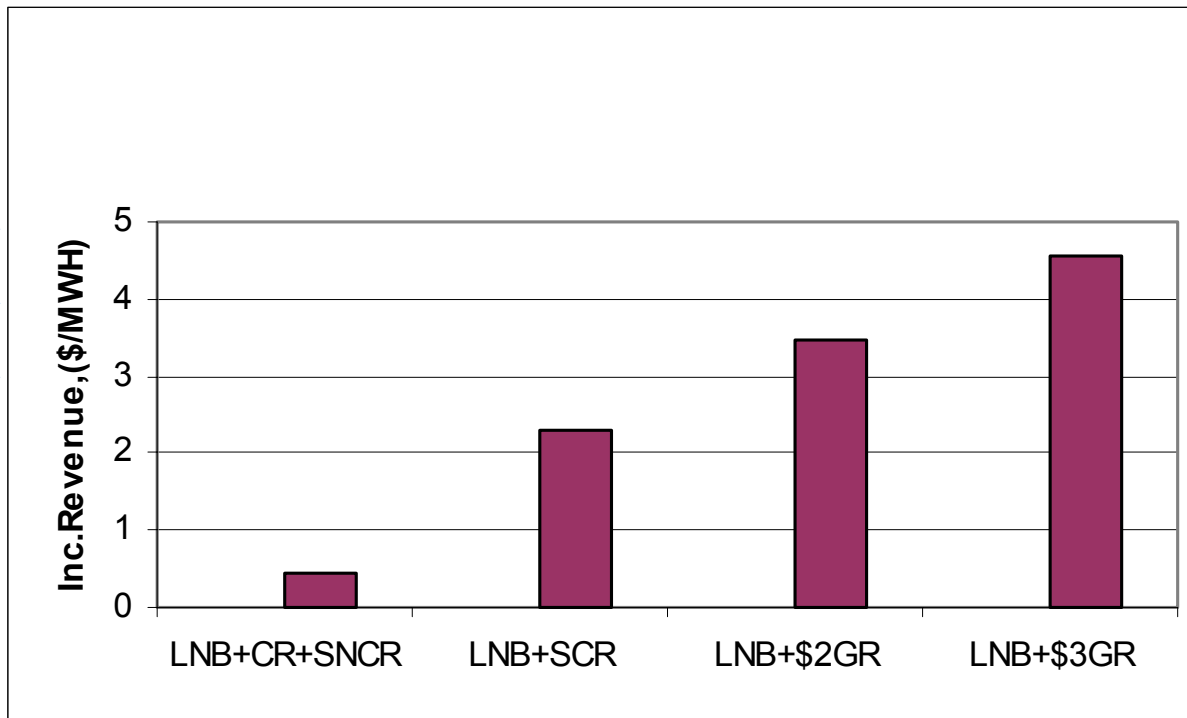
SNCR=Non-
Catalytic Reduction

\$2GR=Gas Reburn
@ \$2/MMBtu

SCR=Catalytic
Reduction

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Incremental Revenue Needed for Various NO_x Processes



LNB=Low NO_x
Burner

CR=Reburn with
Coal

SNCR=Non-
Catalytic Reduction

\$2GR=Gas Reburn
@ \$2/MMBtu

\$3GR=Gas Reburn
@ \$3/MMBtu

SCR=Catalytic
Reduction

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Coal Tech's Combined SO₂/NO_x Process

- u Tests in 20 MMBtu/hour- Combustor Boiler with combined injection of NO_x and SO₂ reducing agents yielded 80% reduction for both pollutants
- u Recent, continuing tests with improved post-combustion SO₂ reduction process yielded to date 80% reduction at reagent cost of about \$100/ton of SO₂ removed.
- u Process capital cost is in several \$/kW range

General Conclusions

- u Staged Combustion/Low NO_x Burners with Coal Tech's SNCR Process achieved 0.15 lb/MMBtu EPA 2003 Limit @ several \$/kW capital cost & about \$400/ton of NO_x removed
- u Addition SNCR injection in fuel rich zone, without reburn, reduced NO_x to 0.075 lb/MMBtu
- u Reburn needs liquid fuel for efficient use
- u Combining NO_x removal with low cost SO₂ process will essentially eliminate both